Deep Energy Retrofits - Occupant Behavior

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Given our training as building performance professionals, designers, engineers or construction professionals, it is easy to think of a deep energy remodeling project as a purely technical matter. All of the important decisions and factors affecting performance before and after the project are those we've been taught to consider—HVAC, hot water system type, airtightness, cellulose versus fiberglass, foam board versus spray polyurethane foam, etc. This is an asset-based approach, which ignores the occupants. But the real rule of home performance and home energy use is variability. If we hold all of the building's technical features constant and place different occupants in those buildings, very different energy uses can result. In most cases, who occupies the home is more important than what type of insulation you use, or whether the walls are R 23 vs. R30, or whether the home is 3 vs. 2 ACH_{50}. Controlling for variable behaviors is exactly what we try to do when performing an asset rating of a home, such as a HERS assessment or Passive House certification. Yet unsurprisingly, evidence suggests that our building simulation models can become more accurate for a given house when we include actual operational information, such as thermostat set-points, appliance usage, etc (Ingle et al., 2012). Contrary to the common asset-based approach, experience shows that a deep retrofit guided by the home occupants' behavior, needs, patterns, and desires will be the most successful, in terms of actual performance, cost-effectiveness, willingness to progress from a design to an actual implementation, and customer satisfaction. This equals more business for you, the contractor.

How can thinking about behavior and occupants make you and your DER projects more successful? Here are some basic tips to improve homeowner engagement and decision making:

- Engage with your clients to find what might motivate them to undergo a DER—is it comfort, control, health, security, energy savings or a combination of factors?
- Design your DER strategy around your client's needs and wants.
- Leverage existing behavior patterns to reduce energy use and discuss new patterns that could have a significant impact.
- Attain better estimates of energy and cost reductions and where energy is going in their specific home. Some people use lots of hot water because they have children, or have many plug loads because they operate a home server and have multiple TVs/gaming systems and large lighting demand due to outdoor security lighting or a basement. Addressing these individual end-uses can make or break a project.

Below, we provide an outline of the DER process—recruitment, planning, use—and some concrete examples and guidance as to how to advantageously incorporate occupant behavior into your projects.

Occupants during project recruitment

Sell the benefits that customers value. Large reviews of U.S. home retrofit programs have suggested that occupants are generally more interested in improved comfort and IAQ, or less noise, maintenance, etc (Fuller et al., 2010). But some are highly motivated by cost savings, and it is important to identify these cases (see below).

Know your market, so that you can sell most effectively. Try to identify the following in your locale:

- What sells?
- What are the drivers of closing a deal (going from talk to work)?
- How can you couple DER upgrades with other home improvements?
- How can you portray your other retrofit projects in a real-life, social contexts for future marketing purposes (this can include open-house events)?
- What competing desires does energy retrofitting have to be negotiated against? You have to be aware of what people are otherwise spending their remodeling money, and some of it needs to be redirected into energy upgrades. For example, if homeowners are set on replacing windows for aesthetic, maintenance and comfort reasons, ensure that they install climate-appropriate, energy efficient units.

Target the homes most likely to engage in DERs, including **dedicated environmentalists** and **high-usage homes.** Dedicated environmentalists *may* already have low energy use or you can help them achieve that goal. Either way, they are motivated to perform a DER, either because of their dedication to reducing environmental impact or their desire for a better performing home. High-usage homes have the greatest potential for cost-effective energy savings and carbon emissions reductions. These can be identified as homes with substantially higher energy consumption than the regional average.

Occupants during project planning

Understand the occupant's interest, needs, wants and expectations. Ranking occupants on the following categories will help you generate insight as to how best to meet their needs and create a successful project.

- Social and personal background
    - Familiarity with home ownership, maintenance, upkeep?
    - Any past experience with remodeling?
    - Cultural notion of what a "good home" is?
    - Multiple decision-makers and styles/approaches?
    - Husband vs. wife team?
    - Trust in professionals
- Resources
    - Budget
    - Time/availability
    - Competencies/skills
    - DIY contributions, including design and/or construction
- Tolerance for disruption
    - This could suggest things like an exterior insulation retrofit to minimize interior disruption
    - Could also lead to recommendations for over-time deep upgrades
- Hunger for information or curiosity
    - Level of engagement in planning and eventual energy management
    - Active vs. passive

- Knowledgeable about home and its systems, or interested in becoming so?
- Ranking of priorities—saving the planet, energy savings, comfort, noise, lighting quality, aesthetics, costs, cost savings, payback, historical preservation/detailing.
    - Remember, some priorities are overlapping and linked. For example, wall insulation can reduce energy use and noise from outside, as well as improve comfort. Try to identify retrofit strategies that provide as much benefit to the homeowner across as many priorities as possible.
    - A careful ranking of priorities will help in making tough choices during construction that often arise as unanticipated issues are revealed, such as mold or structural damage. For a useful homeowner priorities planning tool click here.

Try to identify the occupant's persona. These categories and rankings may help you better understand the occupants' persona (type), which can help you to understand their motivations, actions and goals. Homeowners vary in terms of their level of engagement (e.g., active vs. passive), their priorities (e.g., money, climate change, pollution, comfort), and the extent to which their behaviors actually reflect their priorities (e.g., stumbling vs. effective proponents of conservation). BC Hydro produced the following helpful list of persona types based upon analysis of customer survey and energy usage data:

- Tuned-out and carefree
- Stumbling proponents
- Comfort seekers
- Entrenched libertarians
- Cost-conscious practitioners
- Devoted Conservationists

Use the persona to inform project strategy. One way in which such persona typing could be useful is for targeting homeowners for a DER. This is illustrated by the *Stumbling Proponent* type. They are interested in conservation in the abstract, but their behaviors are "poor" and metered energy use often high. For example, they identify with environmental causes, but they do not consistently turn lights off when leaving a room. This is a great segment to target for a DER, because they have high energy usage (and lots of cost-effective potential), as well as well-intentioned attitudes and opinions, and you can help them fulfill those values through a DER project.

Another way this type of occupant characterization could be useful would be in system design and controls. An engaged and effective occupant may respond best to systems and controls that give them lots of feedback and opportunity to interact and learn. For example, they can be relied upon to engage in passive cooling strategies, such as window and whole house fan operation, or they can reliably keep interior doors open to facilitate air-mixing in a home with ductless heat pumps. They might also use whole house electricity monitoring to help them diagnose and eliminate energy vampires in their home. In contrast, dis-engaged, set-it-and-forget-it types might benefit more from systems where controls are not in the occupants' hands. This could include a smart thermostat-controlled nighttime ventilative cooling system or a ducted forced air system, and instead of electricity monitoring and feedback, they may benefit more from a post-retrofit electricity audit by a professional and installation of smart power strips.

E**ngage occupants in technical planning early and often.** There is rarely a system whose performance does not vary with behavior. For example, a water heating system may seem like a straightforward

decisions based on Energy Factors, but the performance benefit of tankless water heaters is highly variable depending on piping layout and use patterns. For example, some occupants use more hot water when there is no tank constraining the available amount of hot water. Similarly, a ductless mini-split heat pump can seem like a great option that eliminates ducts and has fabulous energy performance. But occupants can tell you if they are willing/able to keep doors open between rooms or have jump ducts added to ensure more even temperature distribution. Some also have strong opinions about the non-traditional-looking interior heat pump head unit. Furthermore, any measures that are included in a project must be understood and accepted by the occupants. For example, several cases of very airtight DERs have been documented with mechanical ventilation systems that are simply turned off or otherwise "defeated" by occupants, whether due to noise, confusion, or discomfort (Berges & Metcalf, 2013). Similar occupant "defeat" efforts have also been documented with high efficiency clothes dryers (and their very long cycle times), as well as with smart, learning thermostats, where occupants have disabled their energy saving features, such as temperature setbacks (Parker, Sutherland, Chasar, Montemurno, & Kono, 2014). Finally, an occupant's willingness/ability to engage in appropriate maintenance is important. For example, an ERV/HRV ventilation system needs periodic maintenance, including filter replacement/cleaning and service of heat exchanger elements.

Use iterative feedback loops of proposed designs. When occupants are engaged in the modeling/design process, it can both illuminate their own behaviors/patterns to themselves, as well as make them more conscious of the energy and environmental impacts of their otherwise baseline behaviors. Energy models can also be useful tools as part of the sales process, in which occupants get a sense of the opportunity in their home, which can reinforce their decision to invest in an energy upgrade.

Strategies for absent occupants. What to do when occupants are not available for the process, such as during affordable housing or other professional development efforts?

- Educate occupants on building systems, operations, maintenance, etc. post-occupancy (see Occupants during use section below).
- Develop best guess as to future-occupants' persona and other aspects listed above. For example, developing an affordable housing DER may take a different direction than developing a market rate, high-end, green certified DER project. Occupant density, cultural attitudes, available resources, and experience with home ownership and maintenance may vary between these two project types; use your local experience as a guide in this matter. For example, if low-income households commonly have large extended families living under one roof in your local community, DER ventilation and hot water systems should be designed to accommodate.
- Given occupant unknowns, simple, robust systems will almost always maintain superior performance over the long term, in the face of neglect.
- Prioritize the use of systems whose performance is relatively independent of occupant behavior.
    - For example, DERs with high levels of insulation and airtightness will be less sensitive to variations in temperature set points.
    - Variable capacity equipment can meet loads, whether they are small or large.

Occupants during use

Educate occupants about a home's systems, design, etc. Provide a *Home Guide*, similar to those required by most green home certifications. Occupants often defeat "smart" or "advanced" systems that do not fill their needs (e.g., smart thermostats, heat pump water heaters that switch to resistance

heating, or efficient clothes dryers with unacceptably long runtimes). Education on the purposes, functions and operations/maintenance requirements are especially important for such items. Provide a summary of the estimated energy uses in the home, to provide an enhanced understanding of what drives consumption in the renovated home. Also provide guidance on future decisions, including the basics of energy efficient and healthy purchasing for items such as appliances, cleaning supplies, etc.

Continue engagement and feedback. Develop a post-project relationship where you can help with energy management, including tracking progress on DER goals, and helping to troubleshoot if performance is not what was anticipated. This continued engagement can also lead to more "word of mouth" advocacy in the owner's social network for deep retrofits and a contractor's services.

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Deep Energy Retrofits - Over-Time, Phased Guidance

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Overview

Completing a deep green upgrade over-time may be an attractive alternative to an all-at-once approach, which can be seen as too costly, disruptive and simply overwhelming. Research in the United Kingdom has demonstrated that retrofits carried out over-time can achieve levels of home performance equal to those achieved by all-at-once DERs (Fawcett, 2013; Fawcett, Killip, & Janda, 2014), and select projects have been successful in the U.S. (Less & Walker, 2014). Over-time home energy upgrades can occur either with careful planning from the outset, or in a piece-meal fashion as time progresses. Both strategies have been shown to produce effective retrofits in the UK, and both paths have their own benefits and liabilities. The guidance we provide below is intended to capture the benefits (and limit the risks) of both approaches.

The following ***potential benefits*** may exist with an over-time approach:

1. Less perceived disruption, because it is spread out over-time.
2. More likely that occupants can continue to inhabit their home continuously, without any need for alternative accommodations.
3. Costs are spread over-time, allowing owners to build up savings between phases.
4. Introduce occupants to the benefits of energy upgrades, thus feeding their desire for further improvements and refinements.
5. More aligned with making incremental deep green improvements, as maintenance and equipment replacement require.
6. Over-time process can inform occupants of the effects of their behaviors, and the potential for behavior modification to reduce both energy use and project costs (through use of human effort rather than technology to achieve savings)

There are also some ***potential downsides*** to an over-time approach:

1. More numerous small disruptions.
2. Difficult to finance traditionally.
3. Costs may be higher, due to repeated fees and fixed costs, such as permitting, inspection and construction labor.
4. Possible need to reinvest in measures that are inadequately addressed, due to a lack of careful and detailed planning.
5. Lower aggregate energy savings and reduction in environmental footprint.
6. Difficult for occupants to delay the gratification of investing in glamorous efficiency measures (such as solar PV or windows), by first investing in the invisibles (insulation and airsealing).